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Ring Based Wearable Bioelectrical Impedance Analyzer for Body Fat Estimation

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Introduction

- Obesity is the most serious public health problem because it is linked to cardiovascular diseases.
- Measuring fat mass is necessary to study the obesity epidemic.
- Fat mass can be estimated by measuring impedance of the human body.

Motivation

- Body fat analyzers play a vital role in the world of e-health today.
- Current commercial body fat analyzers are large and bulky.
- Analyzers providing accurate measurements are very expensive.

Commercial bioelectrical impedance analyzer.

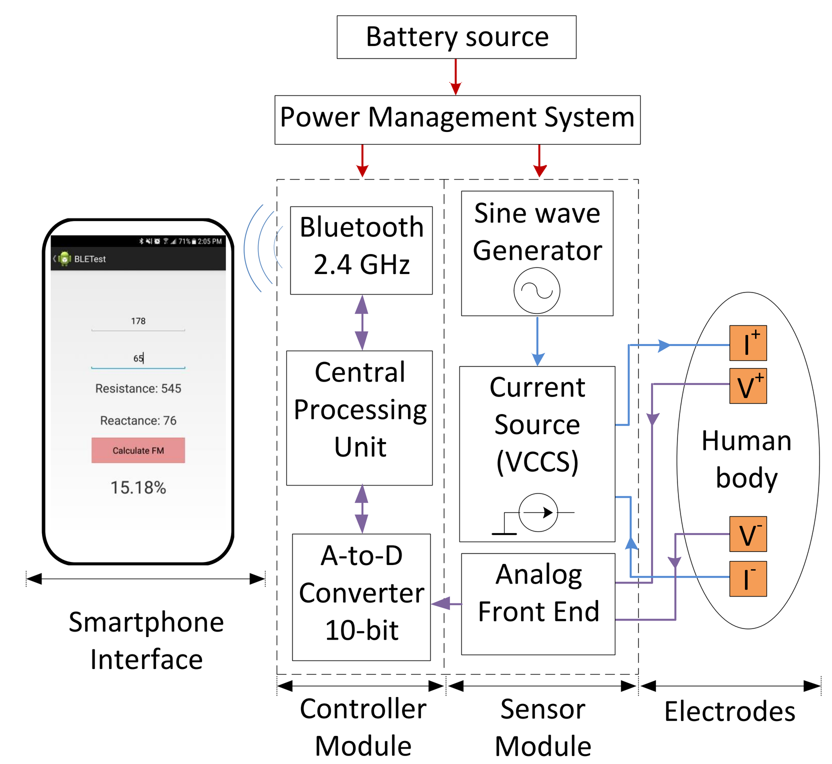
Objectives

- Wearable bioelectrical impedance analyzer for body fat estimation.
- To develop a miniaturized, lightweight, inexpensive, convenient and accurate system.

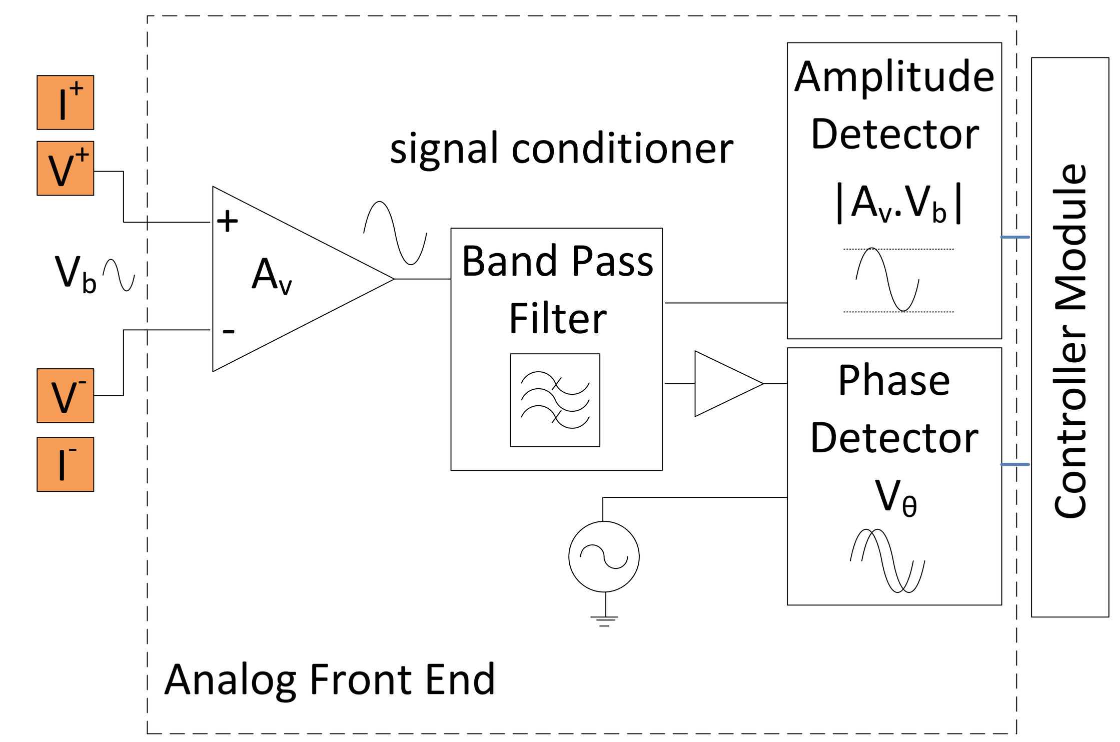
System Architecture

- Two pair of electrodes for interfacing human body.
- A sensor and controller module for signal processing and wireless communication via Bluetooth.
- A smartphone application for user interface and record management.

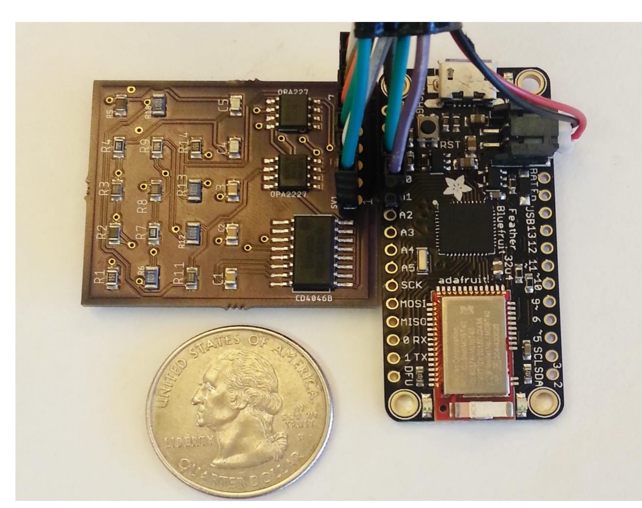
Results



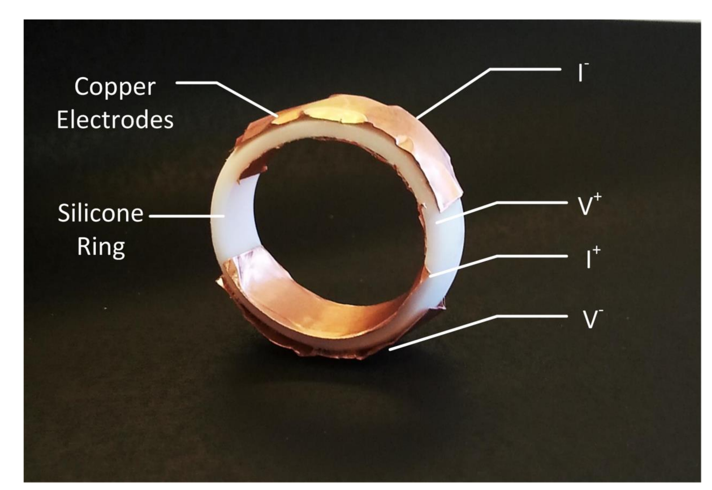
Simplified block diagram of the designed bioelectrical impedance analyzer. All the modules of the designed system are demonstrated.

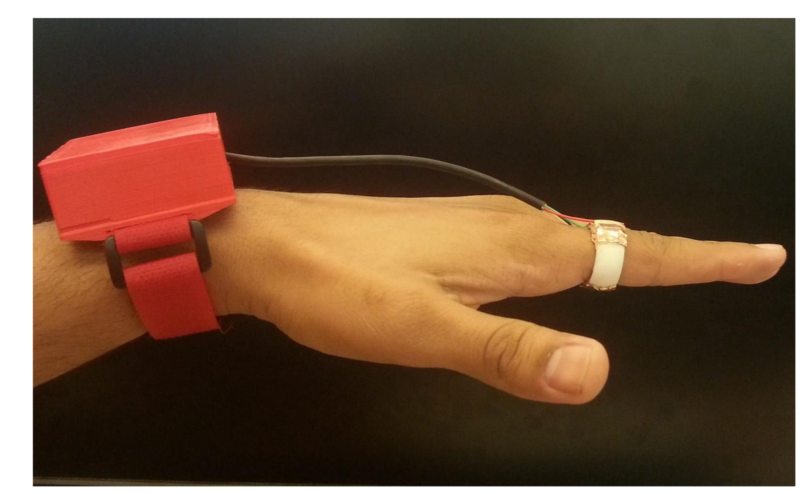


Elaboration of the designed analog front end. This front end is responsible for analog signal processing such as amplification, filtering, amplitude and phase measurement.



Photograph of the sensor and microcontroller module interface.





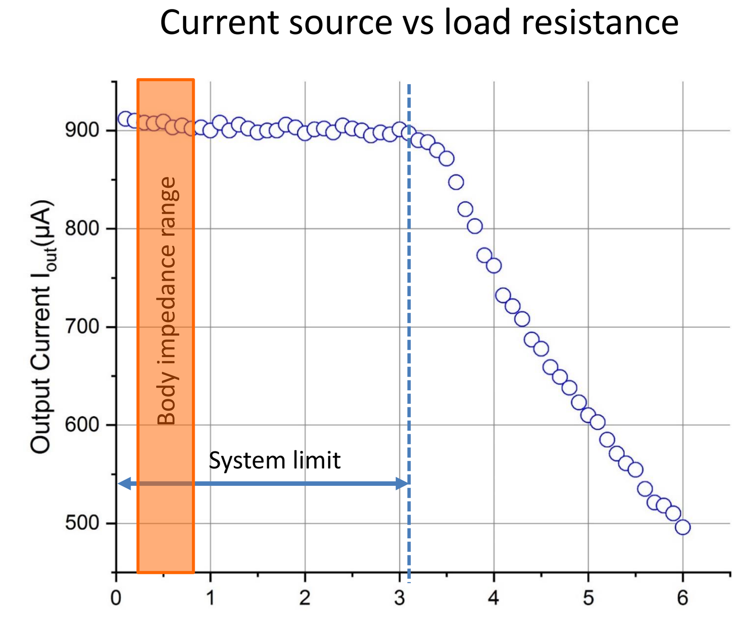
Silicone ring with copper electrodes. Current is applied through source electrodes (I^-,I^+) while voltage is measured through sense electrodes (V^+,V^-). All the electronics is placed in a wrist wearable enclosure.

$$FFM_{kg} = -4.104 + 0.518 \times \frac{Height_{cm}^{2}}{Resistance} + 0.231 \times Weight_{kg} + 0.130 \times Reactance + 4.229 \times Gender$$

$$FM_{\%} = \left(1 - \frac{FFM_{kg}}{Weight}\right) \times 100\%$$

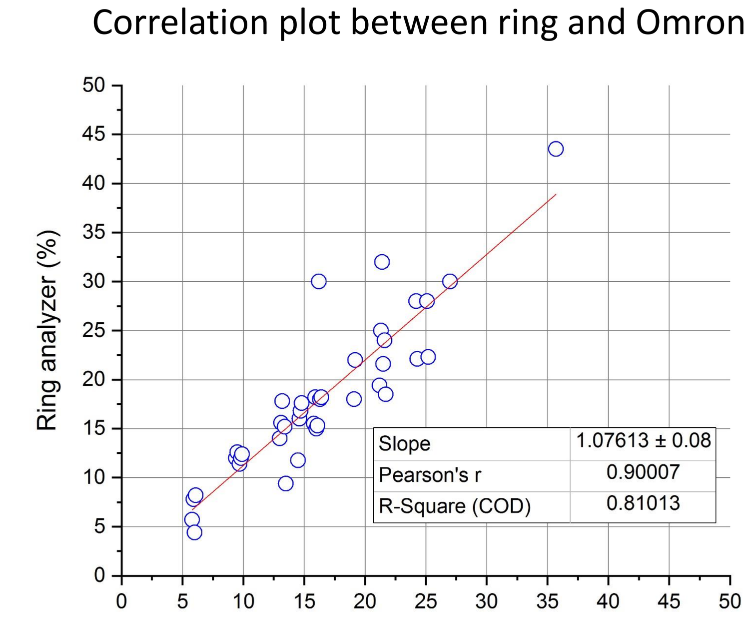
- OMRON hand held upper body fat monitor (HBF-306C)
- Weight: 0.5 kg
- Dimension: 9 × 2 × 6 inches
- Cost: $35
- Sensor technology: Hand to hand
- Battery: 2 AAA
- Electrodes: Aluminum

Current source vs load resistance



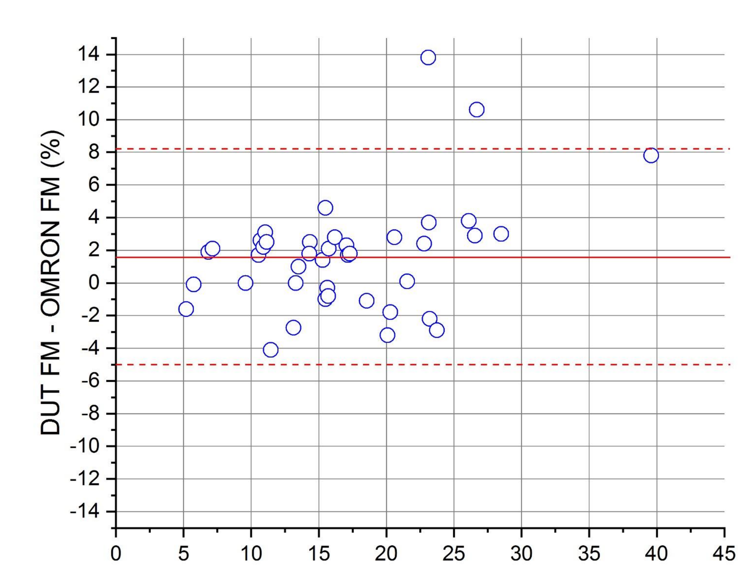
(a)

Correlation plot between ring and Omron



(b)

Bland-Altman plot between ring and Omron



(c)

(a) Safe amount of current (900 μA) is applied to the human body through a voltage controlled current source. Since body resistance is less than 1 kΩ, the system will work very accurate for this range.
(b) Body fat correlation plot between commercial (OMRON) and the designed ring wearable device. The results indicate that there is a strong correlation between the devices with a correlation coefficient of 0.9 (R^2=0.8101, R=0.9).
(c) Bland-Altman plot for our device under test (DUT) and the reference monitor. It can be seen that 38 out of 40 subjects lie within 95% limit of agreement.

Future work

- Miniaturizing the electronic circuit and eventually the overall device.
- Validation for body water, muscle mass and skeletal mass estimation.

Conclusions

- A novel bioelectrical impedance analyzer for body fat estimation.
- Device validated for 40 healthy human subjects against commercial analyzer.
- Great potential to replace commercial analyzers for wearable real-time body fat monitoring.

Acknowledgements

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References

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